

Surveys for the Green and Golden Bell Frog *Litoria aurea* at Meroo National Park on the south coast of New South Wales

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ABSTRACT

We surveyed a population of the Green and Golden Bell Frog *Litoria aurea* in and around two coastal lagoons at Meroo National Park on the south coast of New South Wales. Six survey sessions were conducted between 2002 and 2008. Seven 250 m transects located around the edge of the lakes were surveyed at night for 30 minutes each. The first two survey sessions were conducted when the lakes were closed to the sea and their water levels relatively high. The next two survey sessions were conducted when Meroo Lake was open to the sea and the final one when the lake was closed but the water level low. All surveys were conducted after periods of rain to increase the probability of detecting frogs, particularly *L. aurea*. A total of 54 *L. aurea* was detected in December 2002 and 46 in February 2003. Breeding activity was observed at five sites. Recently metamorphosed frogs were observed during the late summer survey in 2003. *Litoria aurea* bred in brackish water having a salinity of 3 parts per thousand and existed within an environment that contained marine species of fish. A subset of three sites was resurveyed in November 2003 and February 2004 and 2007. Breeding activity was not observed during 2003 and 2004 and only 3-4 frogs were detected. Breeding was recorded in 2007 but no recruitment occurred. No breeding activity was recorded in 2008. Surveys for *L. aurea* should be conducted after periods of intense rain in spring to maximise detectability. For coastal lagoons this should co-incide with periods when they are closed to the sea and the elevated water level floods shallow sedgelands. Major management issues for this population include a more comprehensive assessment of population size and habitat use, artificial opening of the lakes and the potential for the Plague Minnow *Gambusia holbrooki* to colonise the waterbodies from farms higher up in the catchment.

Key words: Green and Golden Bell Frog, Meroo National Park New South Wales, ICOLLs.

Introduction

The conservation of threatened species is dependent on an adequate understanding of their population ecology (Goldingay and Newell 2005a), habitat use (Pyke *et al.* 2002) and distribution. The Green and Golden Bell Frog *Litoria aurea* is known to occur in a wide range of habitats such as natural coastal wetlands, ponds within coastal dune swales, within quarries, dams and ponds (Pyke *et al.* 2002). The species' natural distribution is known from East Gippsland to near Byron Bay in northern New South Wales (Gillespie 1996; White and Pyke 1996). For a widespread and somewhat adaptable species such as *L. aurea*, it is important to understand the habitats utilised in natural and anthropogenic environments so that conservation strategies can be formulated for specific populations across the species' range.

The population ecology of Australian amphibians has only recently received attention with most studies concentrating on species in decline (Richards *et al.* 1993; Gillespie and Hollis 1996; White and Pyke 1996; Goldingay and Newell 2005a,b; Daly and Craven 2007). Broad scale systematic surveys for amphibians are also a relatively recent phenomenon and there have been few studies that utilise systematic surveys to provide quantitative data on a range of frog species (Goldingay *et al.* 1999; Daly *et al.*

2002; Daly 2006; Daly 2007). Rapid declines in species of amphibian such as *L. aurea* underline the need to conduct long-term systematic monitoring of specific populations.

The variation in the size and scale of habitats (small ponds to large wetlands) that *L. aurea* utilises causes problems in adopting systematic methods to determine population densities. We surveyed the population of *L. aurea* at Meroo National Park on the south coast of New South Wales around lakes where the species occupies natural habitat. The lakes are occasionally open to the sea, which may influence their suitability to *L. aurea*. Surveys for frogs have been conducted at Meroo Lake and Termeil Lake previously. *Litoria aurea* was first detected at Meroo Lake in 1995 by D. Andrew (pers. comm.). Subsequently, surveys were conducted by Biosphere (2000) and Gaia Research (2003). Although these surveys focused on *L. aurea* a total of six species of amphibian had been detected in the survey area (NPWS Atlas of NSW Wildlife records).

The aim of our survey was to assess the population size, breeding activity and recruitment to metamorphosing stage of the species at these sites. The study also details the habitat at sites utilised by *L. aurea* for breeding so that quantitative changes in population size could be related to environmental variables, such as the opening of coastal lakes to the sea.

Methods

Study area

Meroo National Park (NP) is located on the south coast of New South Wales (Fig. 1), some 15 km south of Ulladulla and 30 km north of Batemans Bay. The park is composed of two parcels of land separated roughly by the village of Tabourie Lake. The northern section of Meroo NP adjoins Barnunj State Conservation Area (164 hectares). Meroo Lake and Termeil Lake are contained within the southern portion of the park. All of Termeil Lake including the bed of the lake is within Meroo NP. The bed of Meroo Lake is crown land. Both lakes fit the characteristics of an ICOLL (intermittently closed or open (to the sea) lake or lagoon).

The lakes are mostly closed to tidal influences as is evidenced by the absence of mangroves on the lakes' shorelines.

Both lakes have a history of intermittent tidal/non tidal cycles when they are open or closed by a sand barrier at their entrances (Table 1). Large volumes of rain cause the lakes to overtop and break to the sea. During the winter of 2002 both lakes remained closed with some wetland margins flooding creating potentially suitable habitat for frogs to utilise for breeding. Meroo Lake opened to the sea in June 2003. This opening was unusual in that it occurred at the southern end of the lake and scoured out a deep channel. Sand washed back to close the lake in February 2007 and since then the level of the lake has risen as a result of substantial rainfall events (Table 2).

Table 1. Records of opening/closing of Meroo and Termeil lakes.
Data from D. Radford (DEC – Ulladulla) and G. Daly (pers. obs.). na = not available

Date	Meroo Lake	Termeil Lake
December 1994 –December 2005	Closed	na
November 1996	Open	na
December 1996	Closed	na
August - September 1997	Open	na
November 1997- June 1999	Closed	na
November 1999	Open	na
December 1999	Closed	Closed
2000	Open (artificially)	na
2001	Closed	Open (artificially)
December 2002	Closed	Closed
May 2003	Closed	Open
February 2003	Closed	Closed
June 2003	Open	Closed
November 2003	Open	Closed
February 2004	Open	Closed
February 2007	Closed	Closed
June 2007	Open	Closed
January 2008	Closed	Closed

Table 2. Monthly rainfall (mm) recorded at Nowra Hill (Albatross) during the survey period.
Source: Bureau of Meteorology. Annual average for Nowra is 1153 mm. Months declared in drought by the Department of Primary Industries are shown in *italics*.

Month	2002	2003	2004	2005	2006	2007	2008
<i>January</i>	105	46	42	86	38	14	67
<i>February</i>	245	121	79	105	10	287	
<i>March</i>	67	77	65	69	37	90	
<i>April</i>	40	93	92	22	8	48	
<i>May</i>	31	230	17	54	39	18	
<i>June</i>	29	54	11	88	154	323	
<i>July</i>	3	30	45	163	81	54	
<i>August</i>	10	33	20	4	38	47	
<i>September</i>	11	12	57	57	56	26	
<i>October</i>	7	87	209	52	3	12	
<i>November</i>	2	130	81	94	26	115	
<i>December</i>	59	50	103	13	97	78	
Annual totals	609	963	821	807	587	1112	

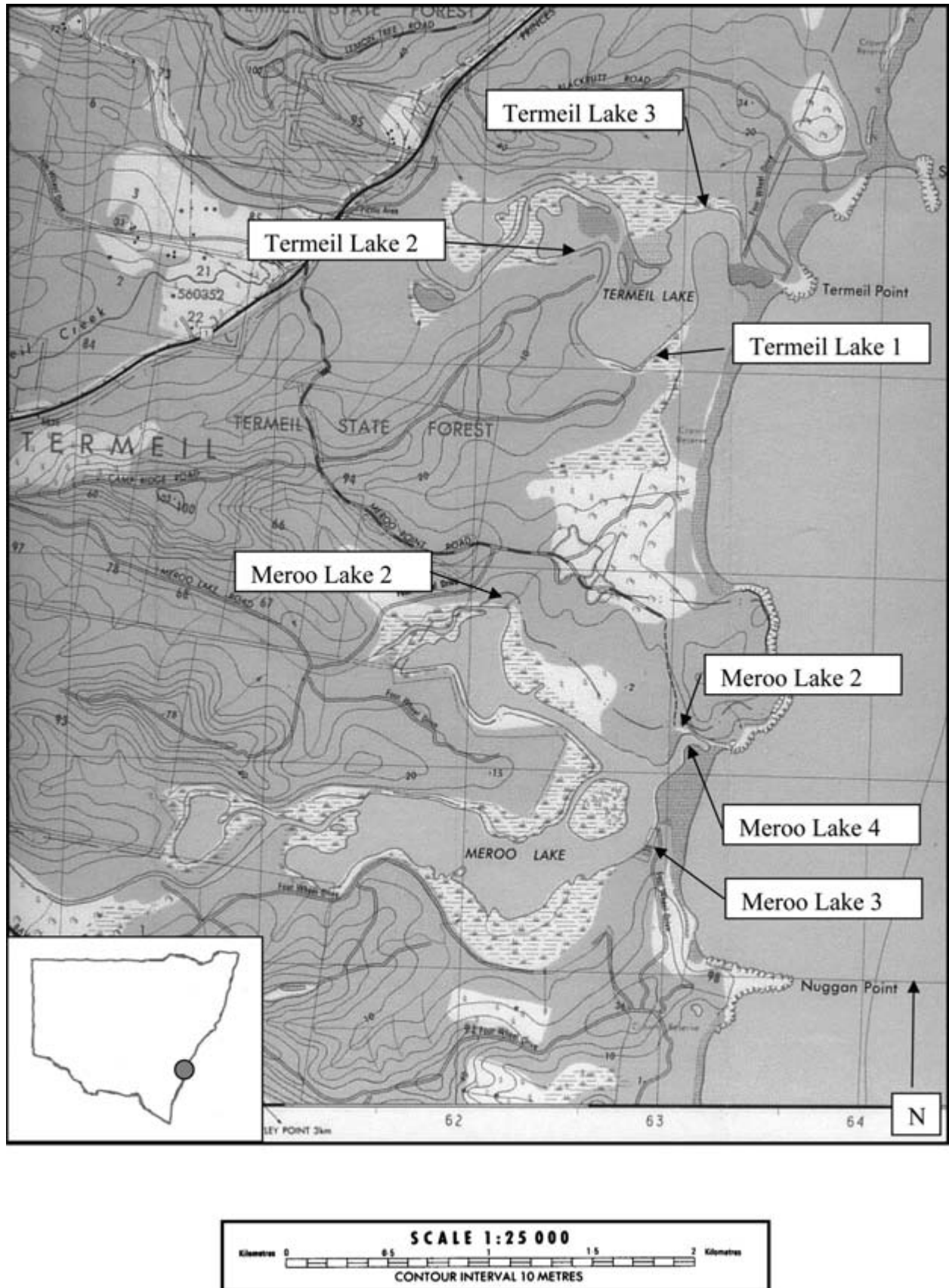


Figure 1. Survey sites for bell frogs. Base map courtesy Department of Lands.

Site Selection

Seven survey sites were located across the two lakes, four along the foreshore of Meroo Lake and three along the foreshore of Termeil Lake (Fig.1). A site consisted of a 250 m long transect. This included sites used in earlier surveys including those where *L. aurea* had been detected, plus sites that covered a range of habitats around the foreshores of the lakes. The survey sites were visited during the day prior to nocturnal surveys in order to describe habitat characteristics such as the surrounding vegetation, existence of shallow pools and presence of fish (Table 3).

Habitat

The most abundant habitat surveyed was sedgeland (sites Termeil Lake 1 and Termeil Lake 3 and Meroo Lake 1 and Meroo Lake 3) where Bare Twig-rush *Baumea juncea* was an abundant species. Adjacent to the sedgeland, paperbark Swamp-oak *Casuarina glauca* forest and *Melaleuca ericifolia* closed shrubland was often present (Table 3; Fig. 2). Meroo Lake 2 was an ephemeral freshwater wetland and contained a different suite of plant species including Spikerush *Eleocharis* sp., Cumbungi *Typha* sp. and Sawsedge *Gahnia sieberiana* (Fig. 3) Meroo Lake 4 contained flooded *C. glauca* forest

(Fig. 4) within an inlet and submerged aquatic weed (Sea Tassel *Ruppia polycarpa*) within Meroo Lake (Figs 5, 6). A comprehensive description of the vegetation communities and species associations of several wetlands is given by deJong (2000).

Assessment of the habitat around Meroo Lake in February 2006 indicated that large areas of *C. glauca* forest had died. This was associated with the prolonged flooding from December 1999 to June 2003.

Frog surveys

All seven selected transects were surveyed in December 2002 and again in February 2003. Surveys were nocturnal and involved spotlighting approximately 250 m transects around the edge of the lakes for 30 minutes each. Spotlighting was done with the aid of 50 watt/12 volt spotlights. The search methods varied with respect to habitat. In areas where Cumbungi or sedgeland dominated then the perimeter of the site was initially surveyed and then a random meander (Cropper 1993) utilised to cover an area termed the site. At sites where there was a definite boundary between the lake and the shoreline then the search area was more linear in nature. A single person usually conducted surveys and if a second person was present they did not record sightings.

Table 3. Habitat of sites surveyed around Meroo Lake and Termeil Lake for *Litoria aurea*.

Site	Depth (m)	Vegetation	Species of fish present
Meroo 1	0.3	<i>Melaleuca ericifolia</i> closed shrubland to 2.5 m with <i>Baumea juncea</i> sedgeland.	Pacific Blue-eye <i>Pseudomugil signifer</i>
Meroo 2	0.4	Ephemeral wetland with <i>Eleocharis</i> , <i>Typha</i> and <i>Gahnia sieberiana</i> to 2 m.	No fish present
Meroo 3	0.3	<i>Baumea juncea</i> sedgeland with <i>Melaleuca ericifolia</i> and <i>Gahnia sieberiana</i> on western edge of transect.	Eel <i>Anguilla</i> sp., Pacific Blue-eye and mullet <i>Mugil cephalus</i>
Meroo 4	1.3	<i>Casuarina glauca</i> forest grading to <i>Melaleuca ericifolia</i> closed shrubland to 2 m at inlet and <i>Ruppia polycarpa</i> in lake.	Eel, Pacific Blue-eye, mullet and bream
Termeil 1	0.2	<i>Melaleuca ericifolia</i> closed shrubland to 2.5 m with <i>Baumea juncea</i> sedgeland.	Eel, Pacific Blue-eye
Termeil 2	1.0	<i>Casuarina glauca</i> forest plus <i>Melaleuca ericifolia</i> closed shrubland to 4 m at western end of transect	Pacific Blue-eye, Gudgeon <i>Gobiomorphus coxii</i>
Termeil 3	0.2	<i>Melaleuca ericifolia</i> closed shrubland to 2.5 m with <i>Baumea juncea</i> sedgeland.	Pacific Blue-eye



Figure 2. Termeil Lake site 1 is thickly vegetated with Swamp Paperbark *Melaleuca ericifolia* and is where a small freshwater creek enters the lake.



Figure 3. Meroo Lake site 2 during December 2003 when free water was not present.



Figure 4. Part of Meroo Lake site 4 was shaded by a dense canopy of Bangalay *E. botryoides* and She-oak *C. glauca* but was used by bell frogs for breeding.



Figure 6. Part of Meroo Lake site 4 looking south to site 3.

Surveys were initiated the night after significant rain events to co-incide with conditions that would stimulate breeding activity in frogs. Approximately 60 mm of rain fell within two days before the first two surveys. The first survey was conducted at the beginning of summer and was considered to be the start of the breeding season because prior to that time the area had been in drought (Table 2). The latter survey period was timed to co-incide with the end of the breeding season when juveniles would be present if reproduction had led to recruitment to the metamorphling stage. Surveys were conducted with air temperatures ranging from 18.3° C to 22.0° C. Fish observed during spotlight surveys were identified and recorded.

A subset of three of the above sites (Meroo Lake 2, Meroo Lake 3, Meroo Lake 4) was resurveyed in late November 2003, in February 2004 and again in February 2007. These sites were selected because they contained a variety of habitat types and *L. aurea* had been detected during previous surveys (Biosphere 2000). Approximately 130 mm of rain fell prior to the November 2003 survey,



Figure 5. Part of Meroo Lake site 4 where Bell Frogs were observed calling while resting on Sea Tassel *Ruppia polycarpa*.

80 mm of rain prior to the February 2004 survey and 125 mm prior to the February 2007 survey (Table 4). These surveys were conducted with air temperatures that ranged from 18.1° to 20.5° C. Surveys of all seven sites were conducted in January 2008 and approximately 9 mm of rain had fallen three days prior to these surveys. Salinity was measured by a water quality metre (yeocal 610) near the north-eastern of Meroo Lake by Shoalhaven City Council.

Diurnal surveys were also conducted at the seven sites in December 2002 for a total duration of 3 h. These surveys involved searches for basking frogs and the call of *L. aurea* was broadcast at intervals from a cassette player (Optimus CTR-116) in order to stimulate males to call. No *L. aurea* were detected during these searches so they are not referred to again.

The NSW NPWS *Hygiene Protocol for the Control of Disease in Frogs* (Wellington and Hearing 2001) was followed. The specific measures employed were frogs were not handled and equipment was thoroughly disinfected with anti-fungicide, prior to surveys and between catchments.

Pathology

Swab samples taken from 13 *L. aurea* on 13 February 2007 using the methods described by Kriger and Hero (2006) and analysed by CSIRO laboratory in Geelong Victoria. The analysis of samples was performed in a laboratory, which had no prior exposure to chytrid, and disposable equipment was used. The samples were analysed by Taqman real-time PCR assay in triplicate at dilutions of 1:10. (Hyatt *et al.* 2007).

Results

Frog survey spring 2002-summer 2003

A total of 54 *L. aurea* were detected in December 2002 and 46 in February 2003 (Table 5). *Litoria aurea* was the most common frog found during the December survey.

Table 4. Survey times and date at each site. Elevation of all sites was approximately 1 metre AHD. - = no survey conducted. Times are in eastern standard time.

Site	Easting	Northing	Survey 1	Survey 2	Survey 3	Survey 4	Survey 5	Survey 6
Meroo Lake 1	262300	6070450	1925-1955 h; 1.12.02	1928-1958 h; 23.2.03	-	-	-	19.52-20.22 h; 8.1.08
Meroo Lake 2	263000	6070250	2024-2054 h; 1.12.02	22.13-23.43 h; 23.2.03	1933-2003 h; 28.11.03	1954-2024 h; 3.2.04	1945-2015 h; 13.2.04	21.02-21.32 h; 8.1.08
Meroo Lake 3	262900	6069700	2040-2110 h; 2.12.02	21.30-22.00 h; 23.2.03	2050-2120 h; 28.11.03	2027-2057 h; 3.2.04	2033-21.03 h; 13.2.04	20.48-21.12 h; 8.1.08
Meroo Lake 4	263000	6070150	2121-2131 h; 2.12.02	2054-2124 h; 23.2.03	2009-2039 h; 28.11.03	2104-2134 h; 3.2.04	2112-2142 h; 13.2.04	21.436-22.06 h; 8.1.08
Termeil Lake 1	262900	6072100	2117-2147 h; 1.12.02	1940-2010 h; 24.2.03	-	-	-	20.54-21.24 h; 10.8.08
Termeil Lake 2	262300	6072600	2215-2245 h; 1.12.02	2037-2107 h; 24.2.03	-	-	-	21.02-21.32 h; 8.1.08
Termeil Lake 3	263100	6072850	1935-2005 h; 2.12.02	2140-2210 h; 24.2.03	-	-	-	22.09-22.39 h; 10.1.08

No amplexed frogs were found but breeding activity (calling males and or recently metamorphosed frogs) was observed at five sites, two beside Termeil Lake and three beside Meroo Lake.

Recently metamorphosed frogs were observed at two sites around Meroo Lake during the February 2003 nocturnal survey. A single metamorphosing individual with fully expanded limbs and large tail (Gosner stage 42) was observed on top of floating Sea Tassel at Meroo Lake 3 and six others near the inlet to the *C. glauca* flooded forest (Meroo Lake 4). *Litoria aurea* had bred in water with a salinity of 3 parts per thousand and coexisted with fish such as eels *Anguilla* sp., Pacific Blue-eye *Pseudomugil signifer*, mullet *Mugil cephalus* and bream *Acanthopagrus* sp.

On some transects no (Termeil Lake 2) or few *L. aurea* were detected (Termeil Lake 1). To access Termeil Lake 3 required a walk along the edge of the lake for a distance of approximately 400 m. No *L. aurea* were detected during a traverse of this site and thick beds of *M. ericifolia* edged the lake.

The habitats utilised by *L. aurea* varied from exposed freshwater wetlands (0.4 m deep) vegetated with Cumbungi and Spikerush, sedgeland on the edge of the lakes, flooded areas within closed *C. glauca* forest, to Meroo Lake (up to 1.3 m deep). Males were observed calling from the top of thick masses of the submerged Sea Tassel growing in the lake about 15 m from the foreshore. Although there was variation in the habitats where *L. aurea* was detected, one of the favoured areas was the flooded areas of Bare Twig-rush, which had open patches of shallow (> 0.2 m) water. These areas had been preselected for survey because previous work indicated that flooded sedgeland, without canopy cover and areas of open shallow water is preferred breeding habitat for the species (Daly, unpub. data).

Frog survey spring 2003-summer 2004

The number of *L. aurea* detected in the November 2003 survey was far less than during the previous survey with only four frogs observed (Table 6). Even though the general breeding activity of frogs was high (seven species calling), no *L. aurea* were heard. The level of Meroo Lake was lower than that of the previous surveys as it had opened to the sea during June 2003 (M. Kempster, DEC Ranger pers. comm.). However, at sites where there were depressions pooled water was present.

Only three adult *L. aurea* were detected in February 2004 (Table 6). The level of Meroo Lake and its associated wetlands had dropped further and the sites that contained depressions were reduced to shallow pools. The beds of Sea Tassel on the edge of the Meroo Lake were exposed to air and desiccated. No *Litoria aurea* were observed in the lake.

Frog survey spring-summer 2007

The area had experienced below average rainfall for several years prior to the 2007 survey (Table 2). Seventeen *L. aurea* were observed in systematic surveys and eight opportunistically (Fig. 7). Seven *L. aurea* were observed

Table 5. Number of each species of frog detected at survey sites during Dec 2002 and Feb 2003 (02: 03).

La = *Litoria aurea*, *Ld* = *Litoria dentata*, *Lj* = *Litoria jervisiensis*, *Lp* = *Litoria peroni*, *Lt* = *Litoria tyleri*, *Cs* = *Crinia signifera*, *Lim* = *Limnodynastes peronii*, *Pb* = *Pseudophryne bibronii*. Number of *L. aurea* in brackets represents metamorphlings).

Site Name	La	Ld	Lj	Lp	Lt	Cs	Lim	Pb	Total species
Meroo Lake 1	11: 11	2: 0	0: 0	0: 0	0: 0	3: 2	4: 50	0: 0	4: 3
Meroo Lake 2	0: 6	4: 0	1: 6	15: 4	27: 15	0: 4	4: 65	0: 0	5: 6
Meroo Lake 3	12: 17 (1)	0: 0	0: 0	0: 0	0: 0	0: 0	1: 9	0: 0	2: 2
Meroo Lake 4	14: 11 (6)	0: 2	0: 0	0: 0	0: 0	0: 0	8: 54	0: 0	2: 3
Termeil Lake 1	7: 1	0: 0	0: 0	0: 0	0: 0	2: 2	0: 11	0: 0	2: 3
Termeil Lake 2	0: 0	0: 0	0: 0	0: 1	0: 0	0: 0	1: 2	0: 0	1: 2
Termeil Lake 3	10: 0	0: 0	0: 0	0: 0	0: 0	0: 6	0: 11	0: 2	1: 3
Total	54: 46	6: 2	1: 6	15: 5	27: 15	5: 14	18: 202	0: 2	

at Meroo Lake 2 but no calling or amplexed animals were found. Although sand had closed the entrance of Meroo Lake in February 2007 the water level was low and the areas where *L. aurea* had been seen in the lake were dry. At Meroo Lake 3 the Sea Tassel was relaxed by low coastal herbs but within the closed *C. glauca* forest 10 *L. aurea* were detected. Although the water level was low (50 mm maximum) a few frogs called and one amplexed pair was found. Another gravid female expelled eggs when handled. No *L. aurea* were found during the other systematic survey but opportunistic observations revealed eight animals nearby.

Frog survey summer 2008

The area had experienced near average rainfall in 2007 and significant rain fell in November 2007 (Table 2) leading to a high water level in Meroo Lake flooding sites 2, 3 and 4. Seventeen *L. aurea* were observed in systematic surveys at Meroo Lake 2, 3 and 4 in January 2008 but no calling or amplexed animals were found. The entrance of Meroo Lake was closed and the water level was high. At Termeil Lake the water level was low and pooled (fresh) water was absent at sites 2 and 3.

Other species of frog detected

A total of seven species was detected during the first survey and eight species during the second survey (Tables 5, 6). The species diversity of adult frogs at sites ranged from

2-5. More species of frog were detected at Meroo Lake (7 species) than Termeil Lake (4 species). In particular, Meroo Lake 2 contained a different suite of aquatic plants (Table 3) than the other sites and had the highest species diversity. The relative abundance of frogs was lower at Termeil Lake (average total animals = 19) than Meroo Lake (average total animals = 91). Four hundred and seventeen individual frogs from seven species were detected during the surveys, 125 during the first and 292 during the second survey. However, this figure is conservative, as the number of *Limnodynastes peroni* recorded during the second survey was large and probably an underestimate. The relative species abundance from the combined total of both surveys was *L. peroni* (53%), *Litoria aurea* (24%), *L. tyleri* (10%), *Litoria peroni* (5%), *C. signifera* (4%), *L. jervisiensis* (2%), *L. dentata* (1.5%) and *P. bibronii* (0.5%).

The number of species of frog varied across surveys: spring 2003 (9 species), spring 2002 (5 species), late summer 2003 (7), late summer 2004 (4). The total number of frogs varied also: spring 2003 (133), spring 2002 (91), late summer 2003 (193), late summer 2004 (33). Five species of frog were detected in summer 2008 and most frogs were detected by observation and were not calling. The total number of frogs detected was also low (50) compared to previous surveys indicating a relatively low level of activity.

Fish observed in Meroo and Termeil Lakes

Fish were observed at most of the sites. The most common species was the Southern Blue-eye *Pseudomugil signifiera* but other species included Gudgeon *Gobiomorphus coxii*, mullet and eel. At site Meroo Lake 3 schools of mullet were observed foraging in the shallow areas close to calling *L. aurea*. The largest species diversity of frog was detected at the site that was fish free (Meroo lake 2).

Pathology

No *L. aurea* tested positive for chytrids. However, five of the 13 samples inhibited the internal positive control probably as a result of dirt on the frogs swabbed. These samples were reanalysed at greater sensitivity (dilution rate of 1/100) and four were negative for chytrids. The remaining sample still inhibited the internal positive control and was not analysed further.



Figure 7. Adult frog observed during the day in a pond beside Meroo Lake.

Table 6. Number of each species of frog detected at select survey sites on Nov 2003, Feb 2004 and 13 Feb 2007 (03:04:07). Values are the number of adults for the three survey dates (Nov03: Feb04: Feb07)
Litoria aurea = La, *Litoria dentata* = Ld, *Litoria jervisiensis* = Lj, *Litoria peroni* = Lp, *Litoria tyleri* = Lt, *Crinia signifera* = Cs, *Limnodynastes peronii* = Lz, Pb = *Pseudophryne bibronii*, *Paracrinia haswelli* = Ph, *Uperoleia tyleri* = Ut.

Site name	La	Ld	Lj	Lp	Lt	Cs	Lz	Pb	Ph	Ut	Total species
Meroo Lake 2	1: 3: 7	5: 0: 17	1: 0: 0	10: 0: 1	30: 0	3: 7: 2	23: 13: 18	0: 0: 1	2: 0: 0	9: 0: 0	9: 3: 6
Meroo Lake 3	2: 0: 10	0: 0: 0	0: 0: 0	0: 1: 2	0: 0: 0	0: 1: 1	1: 7: 7	0: 0: 0	0: 0: 0	0: 0: 0	2: 3: 4
Meroo Lake 4	1: 0: 0	2: 0: 0	0: 0: 0	5: 0: 0	1: 0: 0	5: 0: 0	28: 1: 2	0: 0: 0	0: 0: 0	4: 0: 0	7: 1: 1
Totals	4: 3: 17	7: 0: 17	1: 0: 0	15: 1: 3	31: 0: 0	8: 8: 3	52: 21: 27	0: 0: 1	2: 0: 0	13: 0: 0	

Discussion

Population size and regional significance

Meroo and Termeil Lakes appear to support a large population of *L. aurea* within a natural environment. The maximum number of adult *L. aurea* detected in one survey session across seven sites (1750 m) in two extensive wetlands was 54. We detected *L. aurea* in flooded areas of Bare Twig-rush, which had open patches of shallow (> 0.2 m) water and this habitat type is widespread around the edge of Meroo Lake. Additional searches would have recorded more animals.

Goldingay and Newell (2005a) made an estimate of calling males at Yuraygir NP on one night at 75 yet pit tagging at that site led to estimates of >100 males. In another example a maximum of 63 *L. aurea* were counted around the periphery of Coomaditchy Lagoon on one night (distance of approximately 1000 m) (Goldingay and Lewis 1999), pit tagging indicated a population of >340 adults (Goldingay and Newell 2005b). Based on these estimates and the extent of potential habitat in relation to survey area at Meroo Lake, we suggest the population of adult *L. aurea* is likely to be several hundred animals.

White and Pyke (1996) state that outside the greater Sydney area most *L. aurea* populations are small, numbering less than 10 individuals. The current survey indicates that this is an under-statement. Meroo NP may have one of the largest and most significant populations of *L. aurea* in NSW and is listed as a key population in the draft recovery plan for the species (DEC 2005). Given the size of the adult population detected within a relatively small portion of the total habitat around the lakes and that the area has minimal human interference the population is considered nationally significant.

Previous surveys (Biosphere 2000, E, Burns pers. comm.) only detected a maximum of eight *L. aurea* during qualitative surveys. This was partially due to search effort and areas being less extensive than in the present study. However, the variation in the number of *L. aurea* detected over several years at our sites also indicates that large variations in counts do occur. This has been demonstrated in other studies. For example at Port Kembla in Wollongong counts of *L. aurea* ranged between 0-63 adults in one study (van de Mortel and Goldingay 1998; Goldingay and Lewis 1999). Yet a mark-recapture study (pit tagging) indicated the number at one breeding site may exceed 150 adult frogs (Goldingay and Newell 2005b).

The variation in the number of frogs detected was influenced by rainfall events and the presence of flooded wetlands. The highest number of animals detected coincided with closure of the lakes, coupled with significant spring and summer rain events that flooded the ephemeral ponds and sedgeland areas. This result has implications for survey methods and timing. Diurnal searches (including call playback) may not be an appropriate survey method but can act as a supplement. More accurate methods for

Table 7. Number of each species of frog detected at survey sites during January 2008. Values are the number of adults for this three survey date.

La = *Litoria aurea*, Ld = *Litoria dentata*, Lj = *Litoria jervisiensis*, Lp = *Litoria peroni*, Lt = *Litoria tyleri*, Cs = *Crinia signifera*, Lim = *Limnodynastes peronii*, Pb = *Pseudophryne bibronii*

Site Name	La	Lp	Lt	Lim	Pb	Total species
Meroo Lake 1	0	0	0	8	0	1
Meroo Lake 2	6	5	4	1	1	5
Meroo Lake 3	5	0	0	0	0	1
Meroo Lake 4	6	3	5	4	1	4
Termeil Lake 1	0	0	0	2	0	1
Termeil Lake 2	0	0	0	0	0	0
Termeil Lake 3	0	0	0	0	0	0
Total	17	8	9	15	1	

assessing populations of *L. aurea* should be timed to coincide during spring or summer, after significant rain events that elicit spontaneous calling independent of call playback. For sites beside ICOLLS, these surveys should also coincide with when they are closed to the sea. Searches outside these times will likely give underestimates in population size or worse, false negative results (Daly and Senior 2003). In the case with Biosphere (2000) not detecting *L. aurea* at Termeil Lake, the current work indicates the importance of monitoring under peak favourable conditions to detect presence and maximum numbers of individuals (see also van de Mortel and Goldingay 1998).

Prior to this study the species was not known to occur or exhibit breeding activity within Termeil Lake. Termeil and Meroo Lakes are separated by a distance of 1.5 km, and it is highly likely that frogs disperse between the two waterbodies (Pyke and White 2001; Goldingay and Newell 2005b). Until recently the species was regularly detected at the nearby town of Kioloa (NPWS wildlife atlas records). Further surveys are required within the park and adjacent freehold land to better determine the population size and distribution of *L. aurea*.

Breeding habitat utilised by *Litoria aurea*

Ephemeral coastal wetlands that possess areas of sedgeland and swamps with emergent aquatic vegetation are preferred habitat for *L. aurea* on the south coast of NSW (Daly and Senior 2003; DEC 2007a, b c). Pyke and White (1996) analysed specific environmental habitat components of breeding sites and found most were coastal, freshwater, ephemeral, unshaded and lacked fish. The current survey has broadened the recognised breeding habitat of *L. aurea* to include shaded areas and semi-saline lakes with native fish. Although the species is known to tolerate semi-saline water (7-8 ppt) (Pyke and White 2001) the significance of Sea Tassel for breeding has not been previously recorded.

Litoria aurea was found calling in the shallows on the edge of the lakes in sedgeland adjacent to areas that had patchy sedge vegetation. The mosaic of closed shrubland, sedgeland and shallow open water is important for *L. aurea*. However, breeding (presence of metamorphlings)

was only recorded at sites with thick aquatic vegetation. Although metamorphling *L. aurea* had previously been observed around the edge of Meroo Lake (D. Andrew, pers. comm.) there was no information on where the species bred. The current survey provides evidence of breeding in Meroo Lake and breeding activity at Termeil Lake. However, successful breeding (presence of metamorphs) was only detected on one occasion suggesting breeding does not occur annually.

Observations indicated that under natural conditions the prolonged flooding of the lakes caused sections of sedgeland to die off (some mature Bangalay *E. botryoides* and many Swamp Oak were dead). The patchy nature of dead vegetation subsequently creates small vegetation free areas that are favoured by *L. aurea*. The natural flooding of Meroo and Termeil Lakes is associated with closure to the sea. Artificial opening of coastal lakes is a common occurrence in NSW and may impact on *L. aurea* by altering the natural vegetation succession of these lakes and disrupt breeding opportunities that may be more successful when lakes remain closed under "relatively high" water levels. Although opening of Meroo or Termeil lakes is not necessary for asset protection (houses and other human infrastructure) it is for Avoca Lagoon where *L. aurea* exists and breed (R. Wellington, pers. comm.).

The Plague Minnow *Gambusia holbrooki* is known to eat the eggs and tadpoles of frogs and predation by this fish is listed as a Threatening process under Schedule 3 of the *Threatened Species Conservation Act* (1995). No *G. holbrooki* were detected in Meroo or Termeil Lakes. However, the upper catchment of both lakes is freehold farmland and dams are present. There is a high potential of this exotic fish colonising the lakes.

Litoria aurea co-exists with native estuarine species of fish in areas where aquatic plants provide dense cover. However, only seven metamorphlings were found and the impact of native fish cannot be discounted (see Goldingay and Newell 2005a). No metamorphling frogs were observed around the ephemeral pond that did not contain fish, an observation that was contrary to expectation.

The development of standard survey methodology

The use of systematic and repeatable survey methods is critically important in assessing the abundance of animals. In order to reduce variability induced by random searches we adopted fixed time searches at specific locations. Previous survey data (Biosphere 2000) illustrate the need for better designed surveys to evaluate the local abundance of *Litoria aurea*. Population estimates using mark-recapture methods (Goldingay and Newell 2005a,b) give a more accurate measure of abundance but are expensive and time consuming. To overcome the problem of variation in abundance as a result of weather there is a need to survey several times over a season at sites using standard methods. The current survey methods were modelled on those developed during the comprehensive regional assessment of forest in NSW. It is recommended that where possible researchers adopt these methods as a standard. However, we accept that for frogs such as *L. aurea* the use of systematic methods is problematic because the habitat utilised may not be of adequate size to conduct fixed time transects.

Species diversity related to environmental conditions and survey period

The detection of many species of frog was probably a result of the habitat variation at the sites surveyed, the lakes being closed to the sea and holding a large volume of water that had low concentrations of salt (3.3 ppt) and surveys being conducted immediately after significant rainfall. Most frog species in the Shoalhaven are seasonal

in the time that they breed (Daly, unpublished data). Although the majority of species breed in spring and summer several breed outside these seasons. In the current survey *P. haswelli* and *P. bibronii* were heard calling during late summer and autumn, which is in accord with these species known breeding seasons (Daly, unpubl. data). *Limnodynastes peroni* has been recorded to breed during all months of the year on the south coast, however, breeding activity peaks during late summer and early autumn (Daly, unpubl. data).

Disease

No *L. aurea* at Meroo Lake have been found to be chytrid positive. This raises the questions are all frogs at this site chytrid free and if so why? During surveys sulphur could be smelt and probably has its origins from bacteria in the sediments of the lakes. The element has antifungal properties and may account of the chytrid free status of the frogs.

Future Management

Further survey work is required to quantify suitability of habitats, breeding, total population size, presence of chytrid in other species of frog and the impacts of fish. Surveys should also be conducted in farm dams in the catchment of the lakes for Plague Minnow and an education program delivered on the impacts of this species coupled with eradication. These actions will be part of a management plan for this population and complement other management plans prepared for key populations in the region (DECC 2007a, b, c). Artificial opening of the lakes is not necessary for asset protection and should not occur.

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